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STUDIES ON THE GENUS *DIOSCOREA* L.

R. SUNDARA RAGHAVAN
Central Botanical Laboratory, Botanical Survey of India, Allahabad

ABSTRACT

Morphological and Cytological studies have been made on 13 species of *Dioscorea* and their different polyploid forms. New chromosome numbers have been recorded in *D. deltoidea*, *D. hamiltonii*, *D. belophylla*, *D. sansibarensis* and *D. oppositifolia* var. *linnaei*. Chromosome numbers of the Indian species range from $2n=20$ (*D. deltoidea*) to $2n=100$ (e.g. *D. bulbifera*, *D. esculenta*) indicating a basic number of $x=10$ for this genus. Different polyploid races have been observed in 8 species studied, but a study of the epidermal peelings of the leaves shows that there is not much variation in the epidermal patterns between species as also within the polyploid series of any species. The nature of the tubers, occurrence and size of the bulbils, and the morphology of the epidermal hairs are of much taxonomic interest in the delimitation of species and varieties within a given species.

The tubers of the genus *Dioscorea* are used as food from the distant past and a number of species are known to be medicinal. Many of the wild species contain alkaloids, saponins and glucosides in sufficient amount to render them unsavoury under normal conditions. In times of scarcity however, the tubers are sliced and boiled in water so as to destroy the vitality of the cells, after which they are repeatedly washed in salt or sea water to destroy their acrid contents. Yams form a cheap source of starch and are rich in vitamin B_1, B_2 and B_6. To-day attention is focussed on the possibilities of preparing industrial starch and edible flour from the tubers of *D. alata*, *D. hispida* and *D. bulbifera*, besides extraction of cortisone from *D. deltoidea*, *D. prazeri* and *D. mexicana*. In India the main cultigens are *D. alata* and *D. esculenta*, the others having been slowly displaced by potato, and sweet potato.

Much of our knowledge on this genus is due to Prain & Burkill (1936-38) who have recorded as many as 150 Asiatic species of *Dioscorea*. About 50 species are known to occur in India, out of which Fischer (1928) records 16 species from peninsular India. A recent paper by Santapau (1951) on this genus shows that only nine species are known to occur in Bombay State.

In the Central Botanical Laboratory, a cyto-taxonomic survey of the genus has been undertaken to determine the geographical and cytological variants. The study includes a collection of more than 200 tubers involving 13 species, 12 of which are Indian and one African. Out of the 16 species mentioned by Fischer, 11 have been collected so far. *Dioscorea deltoidea* is known to occur only in the north and has been collected from Dehra Dun and Jammu. *Dioscorea sansibarensis*, a plant of African origin, has been received from Malaya.

In the field, the genus is unmistakable even when in foliage. Even though for an accurate delimitation of the species, floral, fruit and seed characters are indispensable, it is possible to identify most of the Indian forms, by vegetative characters as well. The direction of twining of the stem, the size and nature of the tubers, morphology of the epidermal hairs and the nature of bulbils are all equally important characters of taxonomic value. The nature of twining is a fixed character, and "the twining to the right" is confined to the section *Enantiophyllum* only. Opposite leaves are found only in the section *Enantiophyllum*, and even here the lower leaves are alternate, tend to become opposite a little above, but once again may be alternate or opposite near the tip. In general, alternate leaves are more common in this genus. Compound leaves are limited to the section *Lasiophyton*, but simple leaves are not uncommon amidst the compound leaves. In *Dioscorea tomentosa* earlier developed leaves are simple, while the later developed leaves are compound.

Many of the edible or cultivated tubers are confined to the section *Enantiophyllum*, and the tubers are mostly non-poisonous; the only cultivated tuber belonging to "left" twining section is *Dioscorea esculenta* var. *fasciculata*. However, as mentioned before, many of the tubers belonging to the section *Lasiophyton* though wild are also eaten by hill tribes. The tubers may lie near the surface of the soil or lie deeply buried. Where the tubers are not buried deep, poisonous chemical constituents afford protection against animals (e.g. *D. hispida*, *D. sansibarensis*, *D. deltoidea*). In the wild forms of *D. esculenta*, the tubers are protected by dense spinous dead roots, but the cultivated races are non-spiny, owing to selection by man. In the deep burying tubers, poisons are dispensed with, as the soil itself serves the purpose of protection (e.g. *Dioscorea pentaphylla* var. *linnaei*, *D. tomentosa*, *D. oppositifolia*). In *D. alata*, man by selection has chosen varieties that yield larger tubers rich in starch, but yet are not buried deep.

The epidermal hairs, wherever they are present are of taxonomic interest (Plate I, Figs. 1-8). In *D. deltoidea* hairs are one celled or more generally a filament of two

TABLE I

MORPHOLOGICAL FEATURES IN THE GENUS *DIOSCOREA*

S. No.	Section	Name	Nature of Twining	Bulbil Formation	Nature Of Tubers
1	2	3	4	5	6
	ASIAN SPECIES:				
1.	STENOPHORA	*Dioscorea deltoidea* Wall.	Left	Not observed	Horizontal, lying near the surface of the soil; dry roots remain attached to the tubers as wiry fibers; non-edible, poisonous.
2.	COMBILIUM	*D. esculenta* Burkill	Left	Not formed	Tubers near surface of soil, very small about the size of potato. In cultivated vars. spinous roots absent.
3.	OPSOPHYTON	*D. bulbifera* L.	Left	Plenty	Tubers globose to pyriform, near surface of soil; tubers covered densely with remnants of dead roots. Wild, poisonous, contains dioscorine.
4.	LASIOPHYTON	*D. hispida* Dennst.	Left	Nil	Tubers near the surface, lobed with scanty remnants of roots; very poisonous, wild. Flesh lemon yellow.
		D. tomentosa Koenig ex. Roxb.	Left	None	A bunch of tubers from a knot of tissue, tubers sometimes branched, 1-2 metres long, wild, not generally eaten but hill tribes consume it; very deeply buried.
		D. pentaphylla L. var. *linnaei* Prain & Burkill	Left	Plenty; small spherical or slightly elongated.	Tubers deeply buried, 1-2 metres long, upper surface of tubers covered with roots, wild, edible.
		D. pentaphylla L. var. *jacquemontii* Prain and Burkill	Left	Plenty; elongated, long.	-do-
		D. pentaphylla L. var. *communis* Prain & Burkill	Left	Plenty; spherical, large	Tubers large, not elongated to more than twice the diam., deeply buried, tubers covered with dead roots. Wild, not generally eaten.
5.	ENANTIOPHYLLUM	*D. alata* L.	Right	Plenty; Bulbils are formed in abundance especially in 2n=80 forms when compared to other polyploid races.	Tubers large, not buried very deeply, of various sizes & shapes, non-poisonous, cultivated.
6.	—do—	*D. wallichii* Hook. f.	Right	Nil	Tubers long, 1-2 metres, deeply buried, wild, edible.
		D. oppositifolia L. var. *dukhunensis* Prain & Burkill	Right	None	Tubers single, sturdy, not fragile, 1.5 metres long, wild but edible.
		D. oppositifolia L. var. *linnaei* Prain & Burkill	Right	None	Tubers 2-3, each two to three metres long, very much fragile, wild, edible.
		D. belophylla Voigt	Right	Abundant	Tubers 1-3, deeply buried, wild, edible.
		D. hamiltonii Hook. f.	Right	Seen	Tubers 1 or 2, very long, deeply buried, wild, edible.
		D. puber Blume	Right	Seen	Tubers long, 2-3. Wild, edible, but generally not much sought after.
	AFRICAN SPECIES:				
7.	MACROURA	*D. sansibarensis* Pax.	Left	Seen in Plenty	Tubers as in *D. hispida*, near the surface. Poisonous, non-edible, wild.

Pubescence	Remarks
7	8
Upper surface of leaves glabrous, lower surfaces have scanty hairs which are 1-celled or more generally a filament of 2 cells.	Collected from Dehra Dun and Jammu. Diploid number is 2n = 20. Tuber a source of cortisone. Wild, but at present cultivated for the medicinal value.
T-shaped hairs, with one arm of T longer than the other.	In cultivated varieties the somatic numbers have been determined as 2n = 90 and 100. Cultivated in North as also in South India.
Glabrous.	Common throughout India and has been collected from Bombay, Madras, Nandi Hills, Travancore, Dehra Dun, Mussoorie, Bengal & Madhya Pradesh. Generally the somatic number is 2n = 80, but 2n = 40 & 100 forms have been observed; var. *sativa* the only cultigen, has 2n = 80.
2-3 celled hairs.	Collected from Anamalai, Bombay, Bengal, Kerala & Rewa. Diploid number is always 2n = 40. First to flower at Allahabad conditions. Vegetative period shorter than other varieties.
Hairs very dense and tomentose, two or three celled hairs that are very long.	Collected from Kerala, Anamalai & Coimbatore. The plants had either 2n = 40 or 60 chromosomes. They need abundant rains and are seen in moist rain forests.
Both sides of leaves pubescent but in older leaves upper surface become glabrous. Hairs 2-3-celled.	Collected from Nandi Hills, Anamalai, Kerala, Coimbatore. Mostly 2n = 40, but a few with 2n = 80 chromosomes. Vegetative period longer than in var. *communis*.
-do-	Collected from Bombay; very similar to var. *linnaei* and the diploid number is either 2n = 40 or 80.
Both sides of leaves pubescent, but hairs are longer than in var. *linnaei*.	Collected from Bombay, Coimbatore, Kerala, Anamalai, Bengal and Dehra Dun. All the samples showed 2n = 80 chromosomes only.
Glabrous.	The most commonly cultivated species. About 20 different varieties have been collected from Simla, Mussoorie, Madhya Pradesh, U.P., Bombay, Bengal, Madras and Kerala. Cultivated varieties are invariably 2n = 40 or 2n = 60, but 2n = 80 forms are not uncommon.
Glabrous.	Collected from Coimbatore & Anamalais, 2n = 40 only.
-do-	Collected from Bombay, Coimbatore, Anamalais, Nandi Hills & Kerala, 2n = 40. Inflorescence of male glabrous. Usually vegetative period extends upto Jan.-Feb.
-do-	Collected from Coimbatore & Topslip (Anamalai). Inflorescence of male pubescent. 2n = 80. Vegetative period longer than var. *dukhunensis* extending upto Feb.-March.
-do-	Somatic number has been determined as 2n = 40 & 2n = 80. Seen on the well-drained slopes of hills.
-do-	Seen in moist rain forests & collected from Anamalais. 2n = 40 only. Stem angled as in *D. alata*, but can be distinguished from it by longer capsules, thinner stem, and copper coloured nature of stem when dry.
Petiole & leaves have hairs, basal cell of the hair is surrounded by 3 or 4 cells.	Collected from Travancore only; rather rare. Diploid number is 2n = 40.
Glabrous.	Got from Malaya and is an African species. Diploid number is 2n = 40. Vegetative period very much longer, unlike in *D. hispida*.

cells (Plate I, Figs. 1, 2). In the section *Lasiophyton*, the hairs are two or three celled (Plate I, Figs. 3-6). In *D. pentaphylla* var. *linnaei* the hairs are sparse and very short, but in var. *communis*, the rusty red hairs are longer and denser than in var. *linnaei* (Plate I, Figs. 3 & 4). In *D. hispida*, the hairs are still longer (Plate I, Fig. 5) and do not collapse due to torsion as in *D. pentaphylla*. Further the hairs are retained even after the drying up of the leaves. In *D. tomentosa*, the tomentose hairs are very close together and very long (Plate I, Fig. 6). In all the three species of *Lasiophyton* mentioned above, the hairs are of one type only, differing in length and density alone. In *Dioscorea esculenta* (Section *Combilium*) the hairs are T-shaped, with one arm of the T longer than the other (Plate I, Fig. 8). In the section *Enantiophyllum*, all the species except one, had glabrous stem and leaves. *D. puber* alone has dense hairs covering the leaves and the petiole ; and the base of the hair is surrounded by 3 or 4 cells as shown in Plate I, Fig. 7.

Bulbils are freely formed in this genus with a few exceptions. Morphologically, bulbils are modified branches, but their size and occurrence are of considerable taxonomic interest. In sections *Stenophora* and *Combilium* they are never formed. *D. bulbifera* produces abundant bulbils, the bulbils reaching their maximum size in *D. bulbifera* var. *sativa* with a corresponding decrease in the size of the underground tubers. In the section *Lasiophyton* varietal differences are markedly exhibited in *D. pentaphylla*. Though both *D. pentaphylla* var. *linnaei* and var. *communis* produce spherical bulbils, the bulbils of the former variety are very much smaller in size, when compared to larger bulbils of the latter ; in var. *jacquemontii*, the bulbils are elongate, narrow and as much as 5″ to 6″ in length. No bulbils have ever been reported in *D. tomentosa* and *D. hispida* (Section *Lasiophyton*), but one tuber of *D. hispida* behaved peculiarly. When the sprouting tuber of *D. hispida* (♂) was wrapped up in an alkathene bag and kept in a dark room, it started flowering on the eighth day even though no leaves were produced. After a fortnight about three bulbils were formed but subsequent attempts to raise plants from these bulbils failed. In the section *Enantiophyllum*, only *D. oppositifolia* and *D. wallichii* did not form bulbils. In *D. alata*, the $2n=80$ forms had a proportionately larger number of bulbils, when compared to the other races with lesser chromosome numbers.

The general morphological characters of all the species studied are presented in Table I, so as to give a comparative picture. Studies on the epidermal peelings of the leaves showed that the stomata are confined to the lower epidermis only in all the species. In Table II, results on the observations on the number of stomata in a given field, number of epidermal cells, stomatal index and size of the stomata in all the species as also in the polyploid series within a species are analysed. All the plants were grown under identical conditions at the Central Botanical Laboratory. Two species, namely *Dioscorea belophylla* and *D. puber*, could not be studied as they did not survive long enough.

It is evident from Table II that the stomatal index shows no positive variation interspecific between the different species studied, nor there is any marked difference in the stomatal index or size of the stomata within the polyploid series of any of the species studied. The only exception is *D. tomentosa* where the $2n=60$ form has bigger stomata than the $2n=40$ form. *D. sansibarensis* ($2n=40$) has the lowest stomatal index whereas *D. deltoidea* with the lowest chromosome number viz. $2n=20$ shows higher stomatal index. In the case of *Dioscorea wallichii*, *D. hamiltonii* and *D. hispida*, which in nature grow in rain forests and humid climates, the number of stomata as also the total number of epidermal cells in a given field is very much higher, but the stomatal index is more or less the same. In the case of *D. tomentosa* and *D. pentaphylla* var. *communis*, there is an increase in the number of stomata, but no corresponding rise in the number of epidermal cells with the result the stomatal index is very high.

Dioecism is a characteristic feature of this genus. However in one plant of *D. bulbifera* ($2n=80$), perfectly normal flowers of both sexes were produced in the same plant, the upper flowers of the spike being male and the lower ones female. Meiosis was apparently regular in the pollen mother cells upto the tetrad stage with a normal separation of the bivalents, but the pollen grains were completely sterile. Though seeds were produced in the plants, they did not mature fully under Allahabad conditions.

Cytological studies have been made on all the plants collected and the chromosome numbers have been published in earlier papers (Sundara Raghavan 1958, 1959). In this paper chromosome numbers of those species or races, not earlier dealt with are alone given.

During the course of the present study, two varieties of *D. oppositifolia*, growing side by side but with different vernacular names, were collected from Therkumalai near Coimbatore. *D. oppositifolia* var. *dukhunensis* (Vern. Vetrilaivalli) is the more common plant as compared to var. *linnaei* (Vern. Dhotikilangu) and these varieties are distinguished on the nature of leaves and male inflorescence. In addition to the above features it was found that in var. *linnaei* (Plate III, Fig. 3), the tubers are very long, 2-3 in number, slender to start with but gradually enlarging away from the base, and very much fragile readily breaking up into bits. In var. *dukhunensis*, the tubers are firm, not so long, and are of more or less of uniform thickness and normally only a single tuber is produced from each plant. Cytological studies of a large number of plants belonging to these two varieties have revealed that each variety had a specific chromosome number, var. *linnaei* having $2n=80$ chromosomes (Plate I, fig. 12) as compared to var. *dukhunensis* ($2n=40$). The chromosome number of var. *linnaei* is being reported for the first time. Under identical conditions of cultivation at Allahabad, the

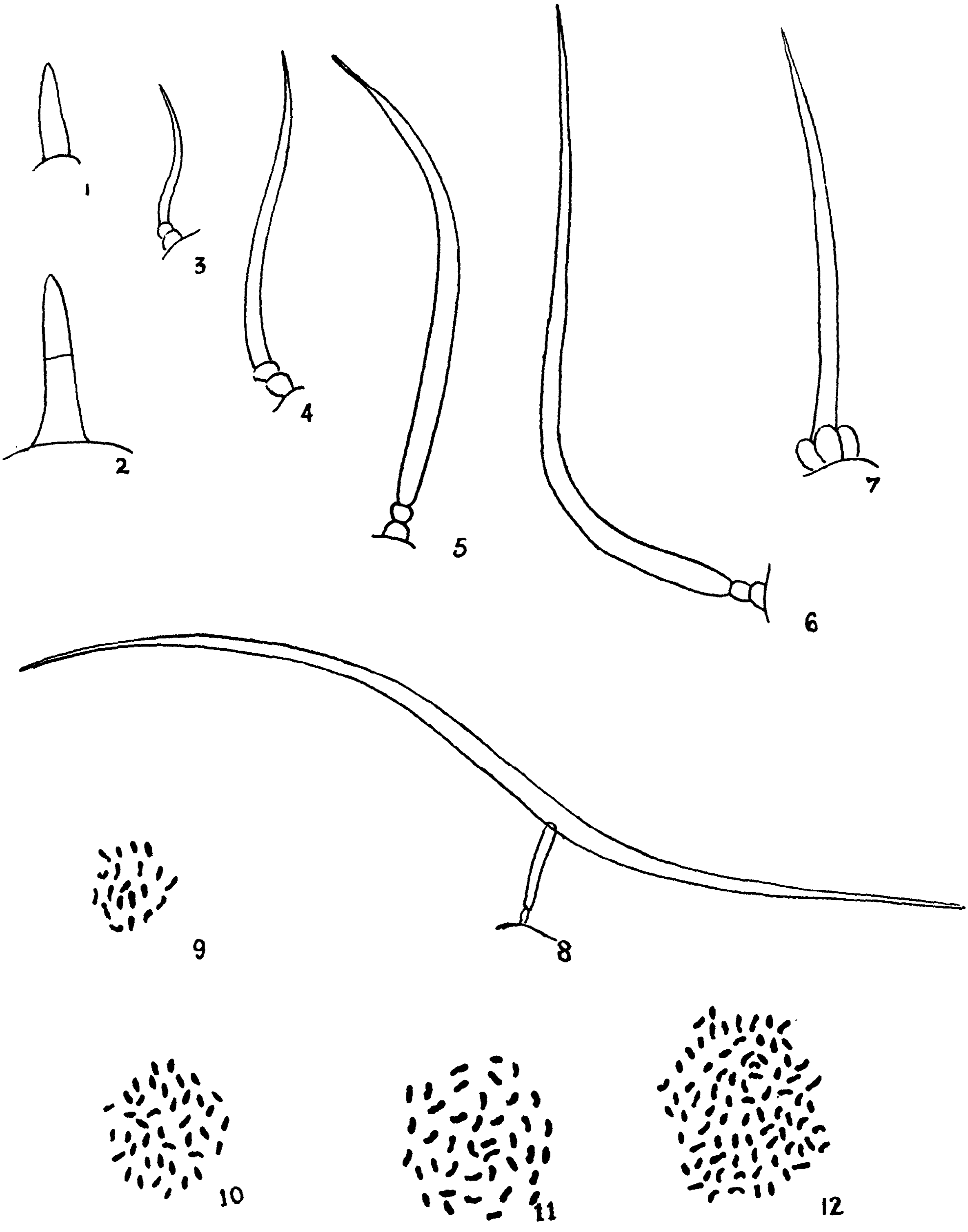

PLATE I. Figs 1-8. Epidermal hairs in ***Dioscorea*** × 500
Figs. 9-12. Somatic chromosomes × 2400

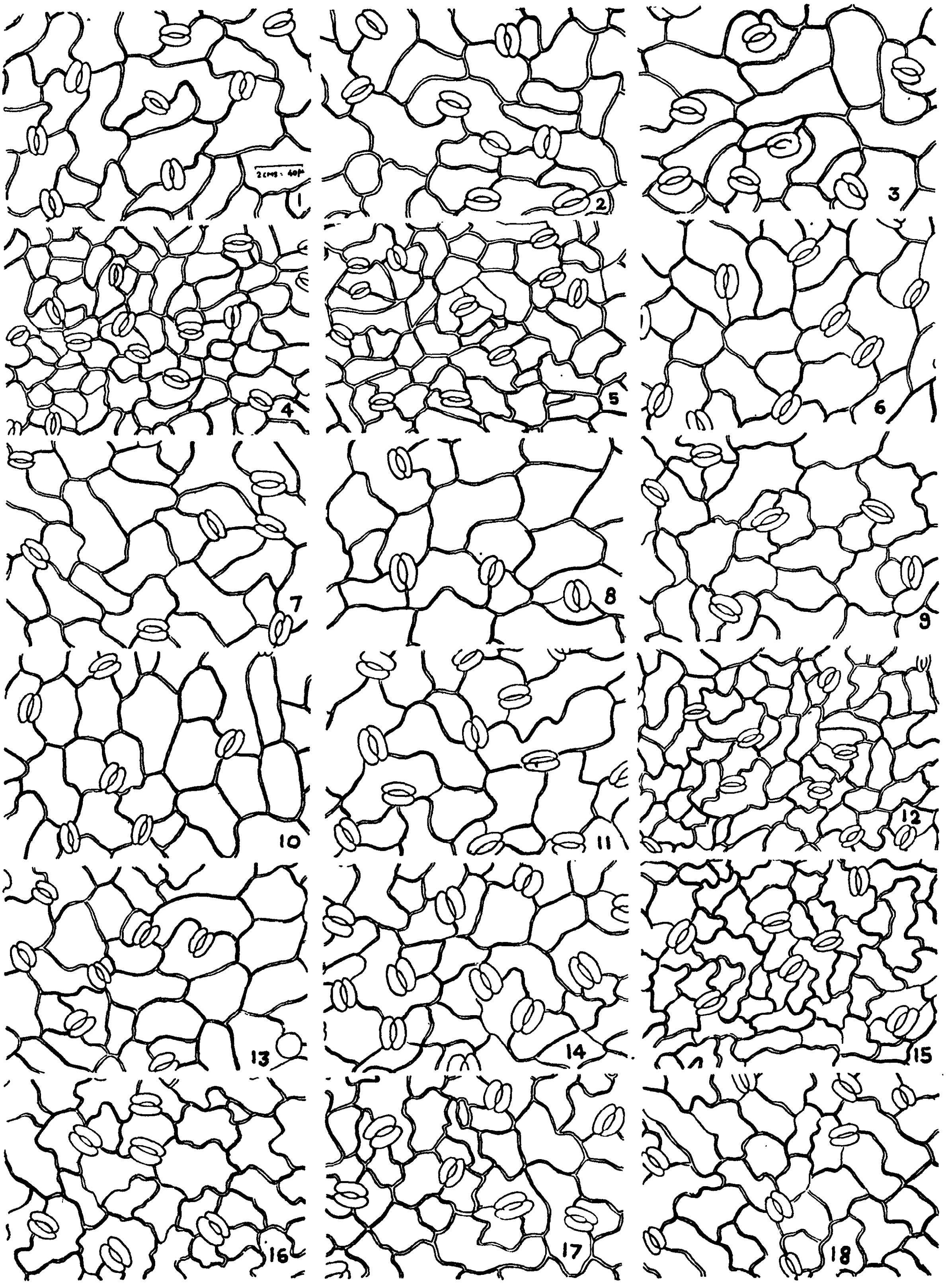

PLATE II. Epidermal patterns in *Dioscorea* × 200

TABLE II

EPIDERMAL PATTERNS IN THE GENUS *DIOSCOREA*

Sr. No.	Name	Chr. No.	No. of stomata in lower epidermis	No. of cells in lower epidermis	Stomatal index	Stomatal measurements	Reference to Figs. in Plate II
1.	*Dioscorea deltoidea*	$2n=20$	15.4	77	20	23μ × 18μ	18
2.	*D. esculenta*	$2n=90$	13.5	68.5	19.7	27μ × 20μ	6
		$2n=100$	17.8	88	20.2	30μ × 18μ	7
3.	*D. bulbifera*	$2n=80$	15	95	15.8	26μ × 20μ	16
		$2n=100$	15.4	98	15.7	26μ × 20μ	20
4.	*D. hispida*	$2n=40$	42	212	19.8	20μ × 15μ	12
5.	*D. tomentosa*	$2n=40$	30	101	29.7	22μ × 20μ	13
		$2n=60$	30	102	29.4	28μ × 25μ	14
6.	*D. pentaphylla* var. *linnaei*	$2n=40$	14.5	79.5	18.3	26μ × 18μ	10
	var. *communis*	$2n=80$	24	80	30.0	28μ × 20μ	11
7.	*D. alata*	$2n=40$	18	93	19.3	30μ × 20μ	1
		$2n=60$	13.8	71.8	19.2	30μ × 20μ	2
		$2n=80$	18	90.8	19.9	30μ × 24μ	3
8.	*D. wallichii*	$2n=40$	48.5	245	19.8	19μ × 14μ	4
9.	*D. hamiltonii*	$2n=40$	32.2	176	18.3	23μ × 16μ	5
10.	*D. oppositifolia* var. *dukhunensis*	$2n=40$	13.3	67.8	19.9	25μ × 20μ	8
	var. *linnaei*	$2n=80$	16.5	86.8	19.0	25μ × 19μ	9
11.	*D. sansibarensis*	$2n=40$	18	175	10.3	25μ × 16μ	15

vegetative period of var. *linnaei* was found to be of longer duration extending up to the end of February.

D. deltoidea, collected from Dehra Dun and Jammu has a diploid number of $2n=20$ (Plate I, Fig. 9), which is the lowest number recorded for the Indian species of the genus. It is interesting to note that *Dioscorea caucasia* Lipsky, *D. tokoro* Makino, *D. gracillima* Miq. and *D. quinqueloba* Thunb. all belonging to the same section *Stenophora*, have $2n=20$ chromosome only (Darlington and Wylie, 1955). The tubers of most of the species belonging to this section are rich in saponins and *D. prazeri* Prain & Burkill, is one of the main vegetable source for the drug cortisone. Researches have shown that *D. deltoidea* can serve as an effective substitute for *D. prazeri* and to-day this species is cultivated on a large scale in Jammu for its medicinal value.

Dioscorea belophylla (Plate III, fig. 2) collected from Dehra Dun has $2n=40$ chromosomes, which number has been recorded for the first time. The tubers are deeply buried 2 to 3 in number and edible.

Dioscorea hamiltonii (Plate III, fig. 1) collected from the Anamalais bears a very close resemblance to *D. alata* and is very much sought after by the tribals as an article of food. All the ten plants examined had $2n=40$ chromosomes only (Plate I, fig. 11), which is a first count for the species.

Dioscorea sansibarensis (Plate III, fig. 4) an African plant was received from Malaya. It is a climber to the left, has large simple, alternate, glabrous leaves and produces plenty of bulbils (Plate III, fig. 5). The tubers are very much like *Dioscorea hispida*, extremely poisonous, and lie near the surface of the soil. The somatic number of this plant has been determined to be $2n=40$ (Plate I, fig. 10).

Tubers and bulbils of the various species of *Dioscorea* were exposed to pile neutrons of varying intensities at the Biology Division of the Atomic Energy Establishment in Bombay. Two tubers from each species were exposed to the following dosages, namely 5×10^{-11} cms^2, 1×10^{-12} cms^2, 2.5×10^{-12} cms^2, and 5×10^{-12} cms^2 and controls maintained. Preliminary observations show that in all the species studied, tubers exposed to lower dosages as 5×10^{-11} cms^2 and 1×10^{-12} cms^2 survived, the higher dosages proving lethal to the plants.

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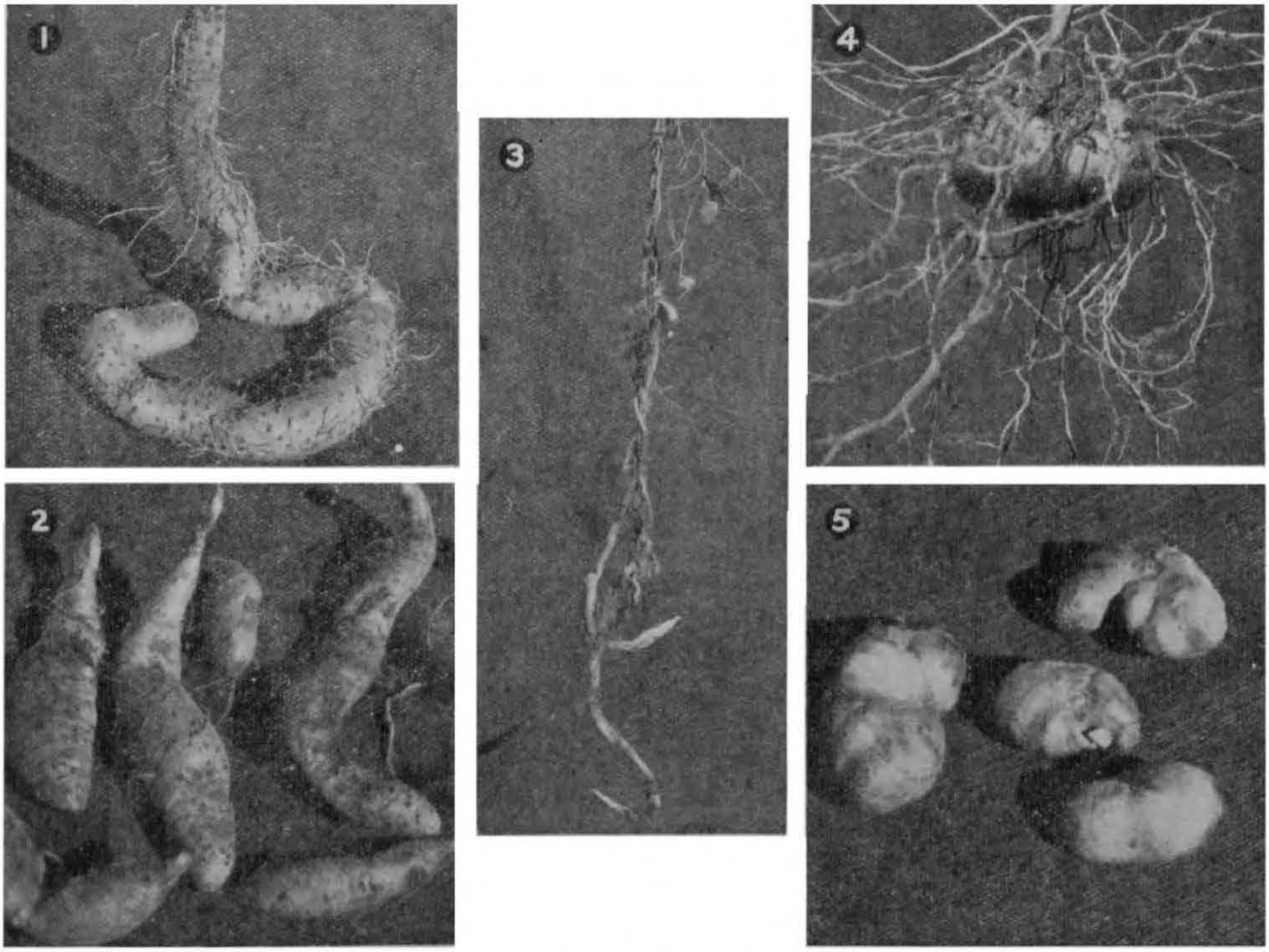

PLATE III. Tubers of ***Dioscorea***